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The extent of the illegal trade with terrestrial vertebrates in markets and households in Khammouane Province, Lao PDR

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Abstract

Wildlife is one of the most important food resources in rural areas and popular among all social layers of Lao PDR. Numerous vertebrate species are sold at the local markets, but a comprehensive understanding of people's involvement and their impact on survival of local populations remains insufficient. This study provides the first interdisciplinary assessment using a questionnaire-based survey approach to investigate both markets and households in Khammouane Province in central Lao PDR. Data were recorded during the dry season (October and November 2017), as well as the rainy season (June and July 2018). We documented 66 traded species, mainly intended for consumption purposes, with more than half of them protected under either national law or international convention/red list. Furthermore, an evaluation of wildlife use from urban to the most accessible rural areas, indicated differences in affordability and trapping behavior. Our results suggest that wildlife availabilities can less and less satisfy the unchanged demands.

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Keywords
Biodiversity crisis, interdisciplinary, Southeast Asia, sustainability, wildlife trade

Introduction

Wildlife trade

The ongoing biodiversity crisis exceeds past rates drastically (Monastersky 2014; Thomsen et al. 2017) with an estimated loss of two to five species per hour (Singh 2002). The major driver for this loss is the over-exploitation of wildlife (Novacek and Cleland 2001) which can play an important role for local food security (Van Vliet et al. 2017, CI 2018) if handled sustainably. Millions of wild animal species and a broad variety of their products are traded every year (Rosen and Smith 2010), whereby the illegal trade alone is estimated to be worth 20 to 150 billion US dollars (Haken 2011), potential livelihoods for numerous people (Millennium Ecosystem Assessment 2005). Wildlife trade is considered the critical link between nature conservation and human sustainable development (Mascia et al. 2003, Broad et al. 2014). Wildlife is not only exploited for commercial trade, but also for self-subsistence (Redford 1992) of growing human populations. Lao PDR is located within the Indo-Burma Biodiversity Hotspot (Myers et al. 2000) and hosts a number of internationally important species (Duckworth et al. 1999). Simultaneously, it is one of the poorest countries in Southeast Asia (Government's Office 2014) measured by development and income (UNDP 2016). Lao PDR was identified as one major origin of seized illegally traded wildlife (Rosen and Smith 2010). Unsustainable trade poses a severe threat to Lao wildlife (Srikosamatara et al. 1992) and the current main challenge to preserve local fauna (Davies 2005, Gray et al. 2018, Srikosamatara et al. 1992).

The use of wildlife can be found in all classes of society, but a majority of Lao people lives under rural conditions (Silverstein et al. 2018) and benefits from wildlife for their income and as a food resource (Nooren and Claridge 2001, Roe et al. 2002). Other purposes are the common use for traditional or religious practices (Zuraina 1982), pet keeping (Chomel et al. 2007) and traditional medicines (Adeola 1992). Numerous species of terrestrial vertebrates are offered at Lao markets (Nijman 2010). Lao PDR holds a responsibility to implement nature conservation measures (Johnson et al. 2009), especially due to its large numbers of native mammals and birds (Giam et al. 2010). These taxonomic groups suffer from massive declines across the tropics with a modelled magnitude of 83% until 2050 (Benítez-López et al. 2017). Furthermore, wild-caught reptiles have occurred throughout Southeast Asian wildlife markets for more than 20 years (Klemens et al. 1995, Duckworth et al. 1999, Nijman et al. 2012) with Lao PDR regarded as a popular source (Stuart 2004). Similarly, the situation for amphibians must not be underestimated as one third of all amphibian species are already globally threatened (Whitfield et al. 2007) of which 70% are confined to tropical forests (Wilkie et al. 2011).

Legislation

Regulations and enforcements have been insufficient to control wildlife trade at both international or national level (Birnie et al. 2009; Rosen and Smith 2010). International cooperation against illegal trade is indispensable in order to effectively ensure conservation (Roe et al. 2002). Today's main wildlife trade regulation mechanism, the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), relies on the capacities, resources, and efforts of signatory countries to implement its guidelines (Bennett 2011). However, the implementation is oftentimes not carried out properly or even fails due to contradictory laws or inadequate enforcement (Nurse 2015). To address this issue, CITES enlists national authorities for 183 states and regional economic organizations worldwide, including Lao PDR (last update: 31.07.2018, CITES 2016). CITES recorded significant trading activities in Appendix-II species in the country (CITES 2018).

Lao PDR's regulations on wildlife use and trade are mainly based on the Lao Wildlife and Aquatic Law (LWAL) (No.7, 2007), in which species are classified according to the Government's recognition of social values and protection requirements. Nonetheless, the regulations largely disregard international statuses and other biological factors. The LWAL lists three protection categories: species considered at risk of extinction and of high value to the society are listed in the Prohibition Category I; their use is prohibited without permission. Species in the Management Category II include those of national economic, social and environmental interest and importance for livelihoods; their use is attempted to be controlled (Schweikhard et al. 2019). A General Category III covers species with stable populations and are subject to a minimum of hunting restrictions. Due to its minor relevance for this study, this category is excluded here. The Prime Minister (No.05/PM, 8th of May 2018) directs authorities throughout the country to take commitments to international laws (The Laotian Times 2018). Additionally, a new Penal Code No. 26/NA issued on 17 May 2017 (effective 17th of October 2018) tightens prosecution of wildlife related violations. In addition, the Ministry of Agriculture and Forestry is instructed to investigate and take action against all businesses and individuals possessing or trafficking of wildlife (WWF Global 2018, The Laotian Times 2018). By limiting human interference within the animal's natural habitats, poaching is presumed to be controlled in a sustainable way (Peres 2002). Within these National Protected Areas (NPAs) and National Parks (NPs) it is easier to enforce restrictions, than trying to restrict people's habits overall (Milner-Gulland et al. 2003). With 24 NPAs and NPs, Lao PDR holds a significant number among Southeast Asian countries which results in a high likelihood for hunted wildlife to originate from these areas.

Khammouane / Hin Nam No Khammouane Province holds three protected areas, representing the remaining major forest areas: Phou Hin Poun NPA, Nakai Nam Theun NP and Hin Nam No NP (HNN), which is most relevant for this study. Covering an area of 92,000 hectares on the Lao-Vietnamese border in Boualapha District, HNN forms one of two largest protected continuous karst areas in the world (Williams 2018). On the 3rd of August 2016, it was submitted to UNESCO World Heritage Centre by the

Lao National Commission for UNESCO to be selected as a UNESCO Natural World Heritage site. It is the first NP in Laos with the status and can currently be found on the tentative list. The objectives of the HNN NP management include foremost the protection of wildlife. However, HNN NP's sensitive ecosystem is under steady pressure, since roughly 22 villages with a total population of 7,000 people (last update: 2005) live in the vicinity of the area. Alongside external stakeholders, many of the inhabitants live off the land and forests with poaching playing a key role (Magiera and De Koning 2013). Due to social factors, such as poverty and food insecurity, market demands and subsequent abandonment of other income (Pruvot et al. 2019), people have been driven to adopt ways of living that degrade the natural environment on which they depend (Broad et al. 2014). Currently, the expansion of land, encroaching into the protected area, is a way to secure basic livelihoods of villagers, especially in years of bad harvests (GIZ and ProCEEd 2014). Besides the constant struggle of linking sustainability and human survival, corrupt interests in Lao PDR hamper or render implementations ineffective, making it one of the latest countries failing to control illegal wildlife trade (Butler 2009).

Objectives

In a former study we provided data towards an annual overview and an evaluation of seasonal market fluctuations regarding offered species (Schweikhard et al. 2019). We assume that knowledge is lacking in the engagement of non-biological aspects in conservation. Therefore, the study combines an assessment of the current trade on-site, but also evaluates the trade drivers which are ultimately human. We aim not only to find out which species are affected but also to understand the role of wildlife in an average household. In addition to market surveys, we interviewed local households, which proved to be successful in portraying biological questions in a social context (White et al. 2005, Jones et al. 2005, Sirén et al. 2004, Drury 2011). This interdisciplinary approach allows the conclusion of a rough estimate of wildlife abundances around Khammouane Province. The assessment of traded species' vulnerability is based on respective categories of the IUCN Red List and CITES, as well as the LWAL Protection List in order to involve a local point of view.

Methods

We investigated the trade of wild-sourced terrestrial vertebrates, namely: mammals, birds, reptiles and amphibians. These four vertebrate classes cover the higher terrestrial fauna of the study area, Khammouane Province (~ 7,200 km^2). Located in central Lao PDR (17°30'N, 105°20'E) and bordering two other Lao provinces, as well as Vietnam and Thailand, the area connects important trade hubs and sets an ideal example for thriving trafficking (Fig. 1). Its capital, Thakhek, is situated along the Mekong River

which builds a natural border to Thailand. Due to its well-connected location, the town is a magnet for regional trading (Nooren and Claridge 2001).

To gain a year-round overview, the study took place in October and November 2017, as well as in June and July 2018, corresponding to dry and rainy season of the prevailing tropical monsoon climate. We surveyed local food markets (Fig. 2), documenting trade activities on-site, while household surveys addressed the consumer behavior (rainy season).

Market surveys

We conducted 66 observational surveys at 15 trade hubs (Fig. 1) (in two cases several markets at one site), which were at least visited twice, to address the main research question: Which species are traded to what extent? Findings with numbers over 100 individuals were rounded to each full ten count. As far as animals could be identified, the data was evaluated further regarding the corresponding conservation statuses based on CITES, the IUCN Red List, and the LWAL Protection List.

In addition to the permanent markets, temporary vending stalls along the highways *Route 12* and *Route 13* were documented, because they offered large amounts of wildlife (Nooren and Claridge 2001). These highways run through Khammouane

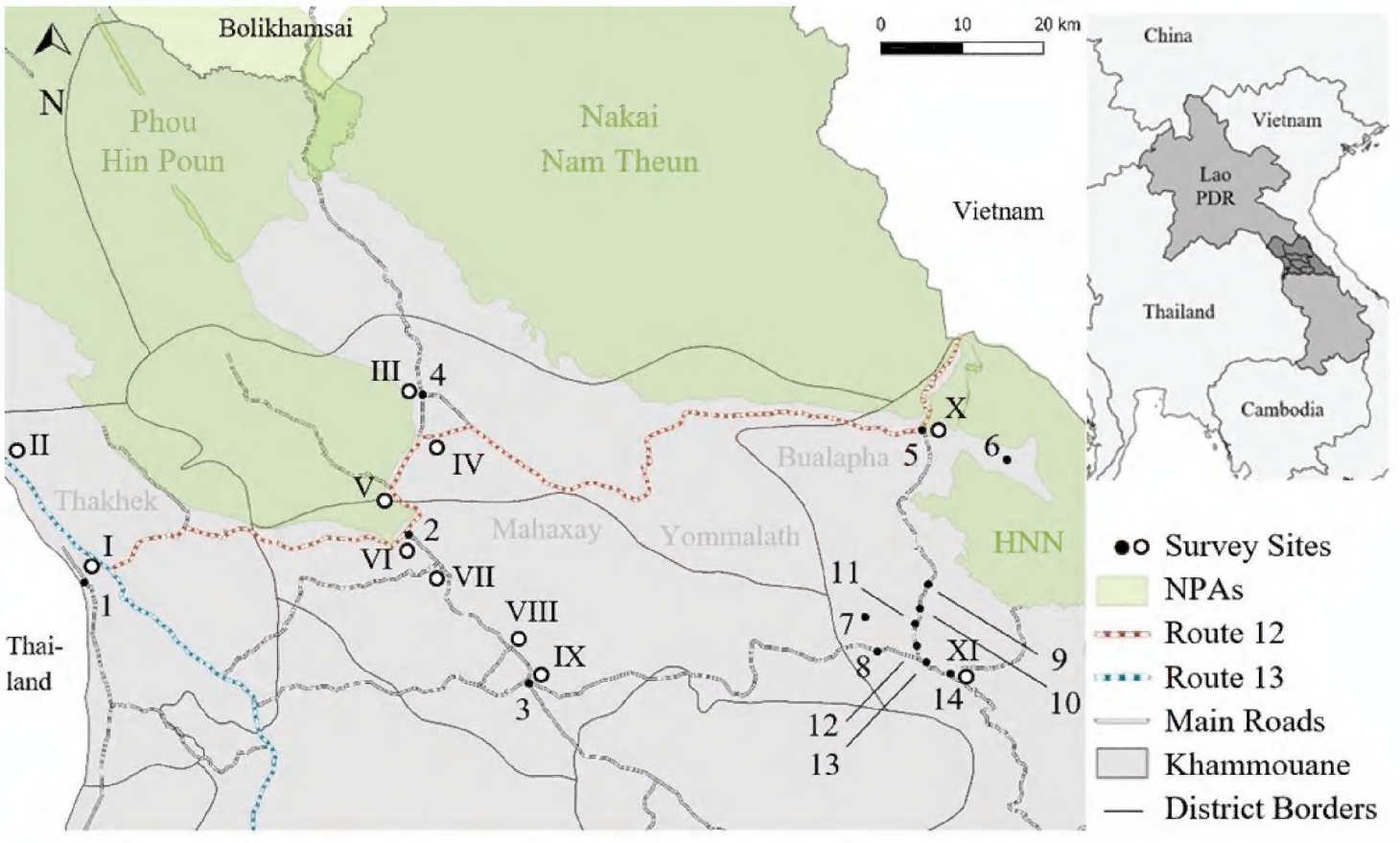

Figure 1. Map of Khammouane Province showing the locations of the household (black, 1–14) and market (white-filled, I–XI) survey sites. Source: Own map, compiled using self-collected GPS data and open source shapefiles ('Laos protected areas and heritage sites' by Open Development Laos (CC-BY-SA); 'Laos-Admin Boundaries' provided by Office for the Coordination of Humanitarian Affairs.

Figure 2. Local market facilities with cages and traps. Phot. T. Ziegler, K. Kasper.

Province into neighboring Vietnam, making them potential routes for the export trade. Eventually, one roadside stall, two convenience stores and one restaurant along these routes were also included in the study.

Household surveys

We conducted household surveys for a broader understanding of people's involvement in wildlife trade, use or trapping behavior. Here, trapping refers to a wide spectrum of wildlife harvesting including the use of snares, hunting with guns, slingshots or dogs, as well as the use of poisoned baits. We surveyed a total of 63 households at 14 sites (Fig. 1) within three different categories: rural areas, transition areas between these and urban areas, which reflect improving degrees of living conditions, infrastructure and trade accessibility with increasing urbanization. A majority of 44 surveys took place in the rural villages of Boualapha District around HNN NP, the main area of interest. In contrast, we included six interviews under urban conditions in the province capital, Thakhek, and 13 in transition areas between wildlife sources and main trade hubs. Participants were selected randomly and interviewed on a voluntary basis. A standardized questionnaire was used for data collecting (see Appendix 1). The interviewers, K. Kasper and J. Schweikhard, were introduced and accompanied by a GIZ employee as a direct translator, assuring the participant's anonymity and

immunity, as well as their understanding of the data being used for scientific purposes only. One interview was conducted for approximately 5–15 minutes and finally transcribed from voice recordings.

Data analysis

Statistical analyses were carried out in R environment for statistical computing (version 3.5.1, R Core Team 2017) using the libraries 'ggplot2' (Wickham 2016) and 'rcompanion' (Mangiafico 2018). To test for significant differences between findings of the dry and rainy season (up to 100 individuals per season), as well as area characteristics and other variables derived from household surveys, Fisher's exact test with a level of significance at $P < 0.05$ was applied. Ultimately, P-values were adjusted using the Holm method to correct the familywise error rate from multiple considerations of hypotheses (Holm 1979). Amphibian findings (with up to 2000 individuals per season) were analyzed using the χ^2-test with a level of significance at $P < 0.05$.

Results

Market surveys

Out of all listed terrestrial vertebrate species present in Lao PDR, large proportions could be found in trade, with majorities in highest conservation statuses (Tables 1, 2). Wildlife was found in all 15 surveyed trading sites (see also Figs 3, 4). A total of 66 species were documented with an average of 218.4 individuals per site. We refer to our previous study for further information (Schweikhard et al. 2019).

Household surveys

Approximately 90% of the surveyed households confirmed use of wildlife. However, differences became apparent in their own trapping involvement and the affordability of wild meat regarding the location of the household (Fig. 5). A majority of the rural population described wildlife harvesting as important for their livelihood and their involvement in trapping differed significantly from those in the urban area. Their trading activity on the other hand was comparably low, which illustrates a high self-consumption rather than trade interest when trapping wildlife. Whereas populations in the urban and transition areas almost entirely perceived wild meat as more expensive, results from rural villagers differed significantly as people found wild meat far more affordable. Also, wild meat was perceived cheaper in terms of sale units, since the cost per unit of domesticated meat was sometimes three times higher than wildlife products, e.g., a whole squirrel. During a survey in the transition area, one respondent claimed that although prices were rising, smaller species, such as rats, squirrels and frogs, were still affordable.

Table 1. Numbers of species native to Lao PDR and listed on CITES Appendices (CITES 2017), by categories of the IUCN Red List (IUCN 2020) and categories of the national LWAL Protection List (National Assembly 2008) in contrast to the proportion of observational data in the scope of the study.

Vertebrate	Conservation Status								
	LWAL		CITES		IUCN Red List				
Class	I	II	I	II	CR	EN	VU	NT	LC
Mammalia	44	15	35	24	11	23	19	8	172
Aves	36	21	6	77	7	6	18	36	656
Reptilia	8	13	3	26	5	10	17	5	121
Amphibia	1	0	0	0	0	6	11	6	112
% found	23.7	4.3	35.0	12.2	56.5	75.6	67.7	89.1	1.89

Table 2. Overview of observed species/genera at risk and their conservation status according to CITES Appendices, the IUCN Red List [Not Evaluated (NE), Data Deficient (DD), Least Concern (LC), Near Threatened (NT), Vulnerable (VU), Endangered (EN) and Critically Endangered (CR)] and the Lao Protection List [Prohibition Category (P) and Management Category (M)], by taxonomic classes and orders. Large amphibian sales units were rounded to each full 5 or 10. Nat. = National Conservation Status; No.S.= number of sightings; Ind.= individuals.

Taxon	Species	Common Name	CITES	IUCN	Nat.	No.S.	Ind.
Mammalia							
Artiodactyla	*Muntiacus* sp.	Muntjac				1	1
	Muntiacus vaginalis	Northern Red Muntjac	none	LC	M	2	2
	Sus scrofa	Wild Boar	none	LC	none	5	10
	Tragulus kanchil	Lesser Mouse-deer	none	LC	none	1	1
Carnivora	*Helarctos malayanus*	Sun Bear	I	VU	P	1	1
	Herpestes javanicus	Javan Mongoose	none	LC	none	2	2
	Ursus thibetanus	Asian Black Bear	I	VU	P	2	2
	Lutrogale perspicillata	Smooth-coated Otter	II	VU	P	1	1
	Melogale personata	Burmese ferret-Badger	none	LC	M	1	1
	Paradoxurus hermaphroditus	Asian Palm Civet	none	LC	M	4	5
	Prionailurus sp.	Wild Cat				1	2
	Prionailurus bengalensis	Leopard Cat	II	LC	none	4	5
Chiroptera	*Cynopterus sphinx*	Greater Short-nosed Fruit Bat	none	LC	M	1	5
	Eonycteris spelaea	Cave Nectar Bat	none	LC	M	2	32
	Hipposideros armiger	GreatHimalayan Leaf-nosed Bat	-	LC	M	1	9
	Miniopterus sp.	Bent-winged Bat			M	1	4
	Rousettus amplexicaudatus	Geoffroy's Rousette	none	LC	-	1	1
Lagomorpha	*Lepus peguensis*	Burmese Hare	none	LC	M	1	1
Pholidota	*Manis* sp.	Pangolin	II	CR	P	2	5
Primates	*Nycticebus bengalensis*	Bengal Slow Loris	I	EN	P	3	3
	Pygathrix nemaeus	Red-shanked Douc Langur	I	CR	P	1	1
Proboscidea	*Elephas maximus*	Asian Elephant	I	EN	P	1	1
Rodentia	*Atherurus macrourus*	Asiatic Brush-tailed Porcupine	none	LC	M	2	2
	Bandicota savilei	Savile's Bandicoot Rat	none	LC	none	1	1
	Belomys pearsonii	Hairy-footed Flying Squirrel	none	DD	none	1	1
	Biswamoyopterus laoensis	Laotian Giant Flying Squirrel	none	DD	none	5	8
	Callosciurus erythraeus	Pallas's Squirrel	none	LC	none	14	26
	Callosciurus finlaysonii	Finlayson's Squirrel	none	LC	none	1	1
	Dremomys sp.	Red-cheeked Squirrel	-	-	none	1	2

Taxon	Species	Common Name	CITES	IUCN	Nat.	No.S.	Ind.
Rodentia	*Dremomys rufigenis*	Asian Red-cheeked Squirrel	none	LC	none	8	16
	Hylopetes sp.	Flying Squirrel	-	-	none	1	4
	Hylopetes alboniger	Particolored Flying Squirrel	none	LC	none	1	3
	Hystrix brachyura	Malayan Porcupine	none	LC	M	2	2
	Laonastes aenigmamus	Laotian Rock Rat	none	LC	P	2	3
	Leopoldamys edwardsi	Edwards's Long-tailed Giant Rat	none	LC	none	5	5
	Leopoldamys sabanus	Long-tailed Giant Rat	none	LC	none	12	80
	Menetes berdmorei	Berdmore's Ground Squirrel	none	LC	none	7	18
	Niviventer fulvescens	Chestnut White-bellied Rat	none	LC	none	3	4
	Petaurista sp.	Flying Squirrel	none	LC		5	7
	Petaurista elegans	Spotted Giant Flying Squirrel	none	LC	none	1	6
	Petaurista philippensis	Indian Giant Flying Squirrel	none	LC	P	1	2
	Ratufa bicolor	Black Giant Squirrel	II	NT	M	7	7
	Rhizomys pruinosus	Hoary Bamboo Rat	none	LC	none	2	2
	Rhizomys sumatrensis	Large Bamboo Rat	none	LC	M	1	1
Scandentia	*Tupaia belangeri*	Northern Treeshrew	II	LC	none	2	3
Aves							
Columbiformes	*Spilopelia chinensis*	Spotted Dove	none	LC	M	3	10
Cuculiformes	*Centropus sinensis*	Greater Coucal	none	NE	P	2	12
Passeriformes	*Acridotheres tristis*	Common Myna	none	LC	M	2	2
Strigiformes	*Ketupa ketupu*	Buffy Fish Owl	II	LC	M	1	1
Reptilia							
Squamata: Sauria	*Gekko gecko*	Tokay Gecko	II	NE	none	1	15
	Physignathus cocincinus	Chinese Water Dragon	none	NE	M	3	10
	Varanus nebulosus	Clouded Monitor	I	NE	M	4	5
	Varanus salvator	Asian Water Monitor	II	LC	M	4	4
Squamata: Serpentes	*Naja* sp.	Cobra	II	DD	M	1	1
	Ophiophagus hannah	King Cobra	II	VU	P	3	15
	Ptyas korros	Chinese Ratsnake	none	NE	none	4	8
Testudines	*Heosemys grandis*	Giant Asian Pond Turtle	II	VU	none	3	3
	Malayemys cf. *subtrijuga*	Mekong Snail-eating Turtle	II	VU	M	14	78
	Trionychidae sp.	Softshell Turtle				1	1
Amphibia							
Anura	*Babina chapaensis*	Chapa Frog	none	LC	none	1	10
	Fejervarya limnocharis	Asian Grass Frog	none	LC	none	19	2083
	Glyphoglossus guttulatus	Burmese Squat Frog	none	LC	none	2	110
	Hoplobatrachus rugulosus	East Asian Bullfrog	none	LC	none	41	2962
	Humerana miopus	Three-striped Frog	none	LC	none	5	395
	Kaloula pulchra	Banded Bullfrog	none	LC	none	3	107
	Leptobrachella sp.	Asian Leaf-litter Frog	none	LC	none	6	1162
	Occidozyga martensii	Round-tongued Floating Frog	none	LC	none	1	70
	Raorchestes parvulus	Karin Bubble-nest Frog	none	LC	none	1	6
	Sylvirana guentheri	Gunther's Amoy Frog	none	LC	none	9	575
	Sylvirana nigrovittata	Sap-green Stream Frog	none	LC	none	5	389

Roughly 84.1% of the respondents confirmed changes in the wildlife market over time. While a majority reported the general demand to remain the same, the availability of wild meats was reported to have decreased and accompanied by increasing prices (Fig. 6). In addition, it was repeatedly mentioned that prices for farmed meat were also rising with one informant speaking of increases up to one third in kilo prices.

Figure 3. Bengal Slow Loris (*Nycticebus bengalensis*) (left); squirrels (*Callosciurus erythraeus*, *Menetes berdmorei* or *Dremomys rufigenis*), bats (*Hipposideros armiger* and *Rousettus amplexicaudatus*) (right) offered at a local food market. Phot. C.L. Ebert.

Discussion

Socio-geographic diversity

Ultimately, the relationship between offer and demand as shown in the study can be a good indicator for wildlife use in the province as well as wildlife population status. By investigating local people's reflection on wildlife availability and accessibility in markets, we demonstrated that available wildlife products fail to satisfy the constant demand. This allows a disquieting view on the issue against the background of an escalating biodiversity crisis, as biodiversity especially in the study area faces an immense loss (Hughes 2017). Most frequently traded species mainly consisted of birds, squirrels, rats and frogs (Fig. 7). This intensity of pressure can negatively affect populations in the long term and driving bird species into extinction since prehistoric times (Duncan et al. 2002).

However, the use of wildlife as meat is no longer a matter of subsistence. This was confirmed by many of our interviewees in the urban areas, who described their preference of wild meat over domesticated meat. Studies from Africa and Asia indicated that an increase in wealth may cause a significant rise in demand, resulting in expanding wildlife markets in urban towns (Robinson and Bennett 2002). In urban areas where bushmeat is much pricier than domesticated meat (Bennett 2002), mainly people of high social status and income consume preferably rare and expensive sorts of wild meat (Shairp

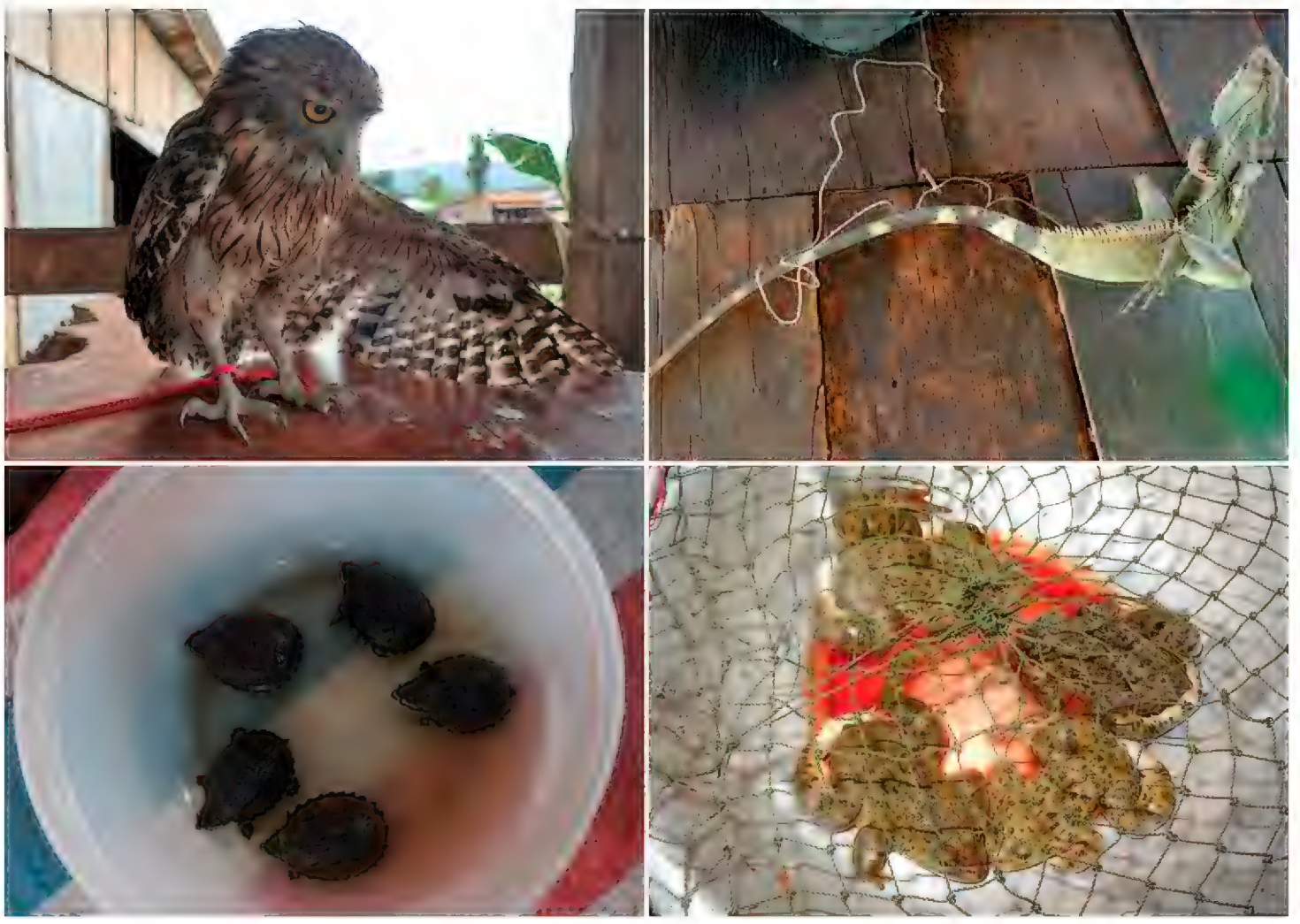

Figure 4. Buffy fish owl (*Ketupa ketupu*) (top left), Mekong snail-eating turtle (*Malayemys* cf. *subtrijuga*) (bottom left), Chinese water dragon (*Physignathus cocincinus*) (top right), and East Asian bullfrogs (*Hoplobatrachus rugulosus*) with broken legs (bottom right) offered at a food market. Phot. K. Kasper, T. Ziegler.

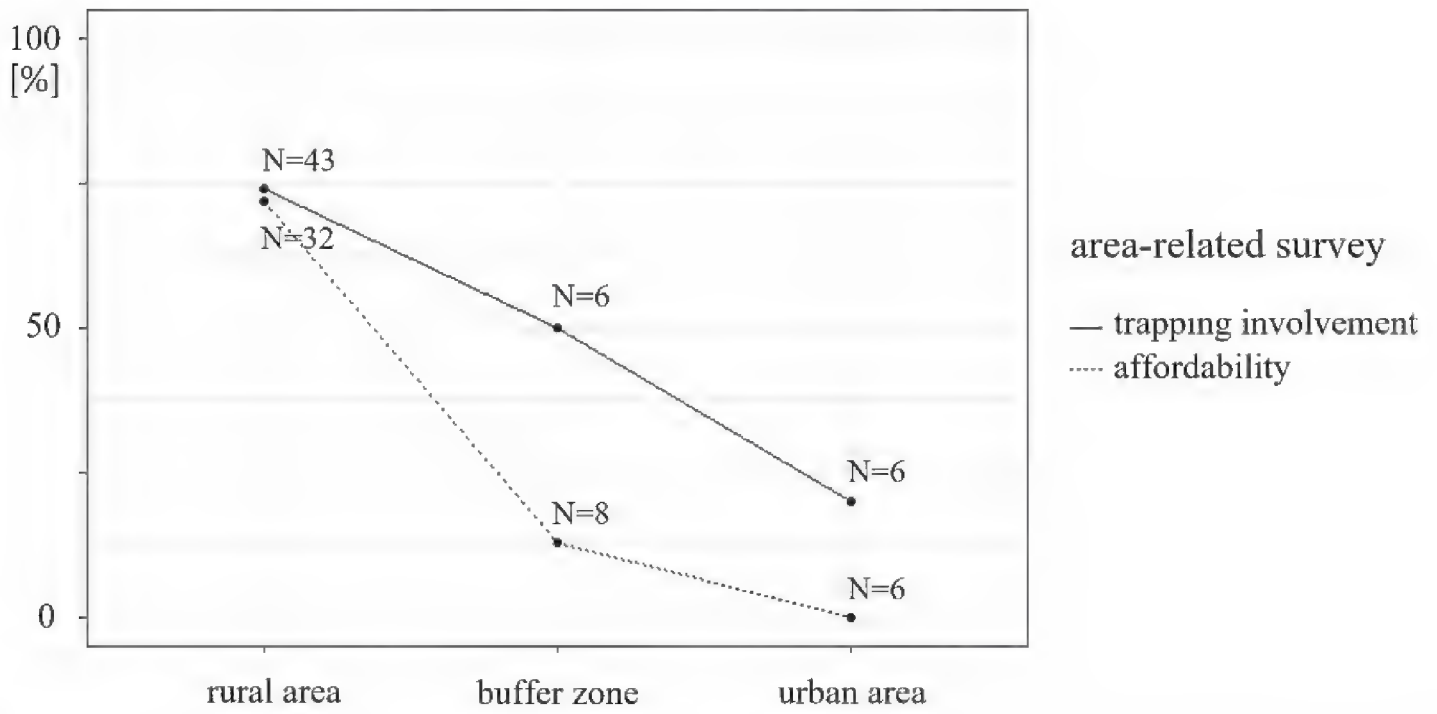

Figure 5. Households along an urbanization gradient (rural, transition and urban area) that depicts their involvement in wildlife trapping activities, and those that claimed rate wild meats on the market more affordable than meats from a farmed source (N = 55, 46). Trapping involvement of households in rural areas differs significantly from that in the urban area (Fisher's exact test, P = 0.032). Regarding wild meats' affordability, households in rural areas differ significantly from the other areas (Fisher's exact test, P=5.928-5), with a difference to transition areas by P = 0.007 and P = 0.005 to the urban area. Data was drawn from the respective interviews.

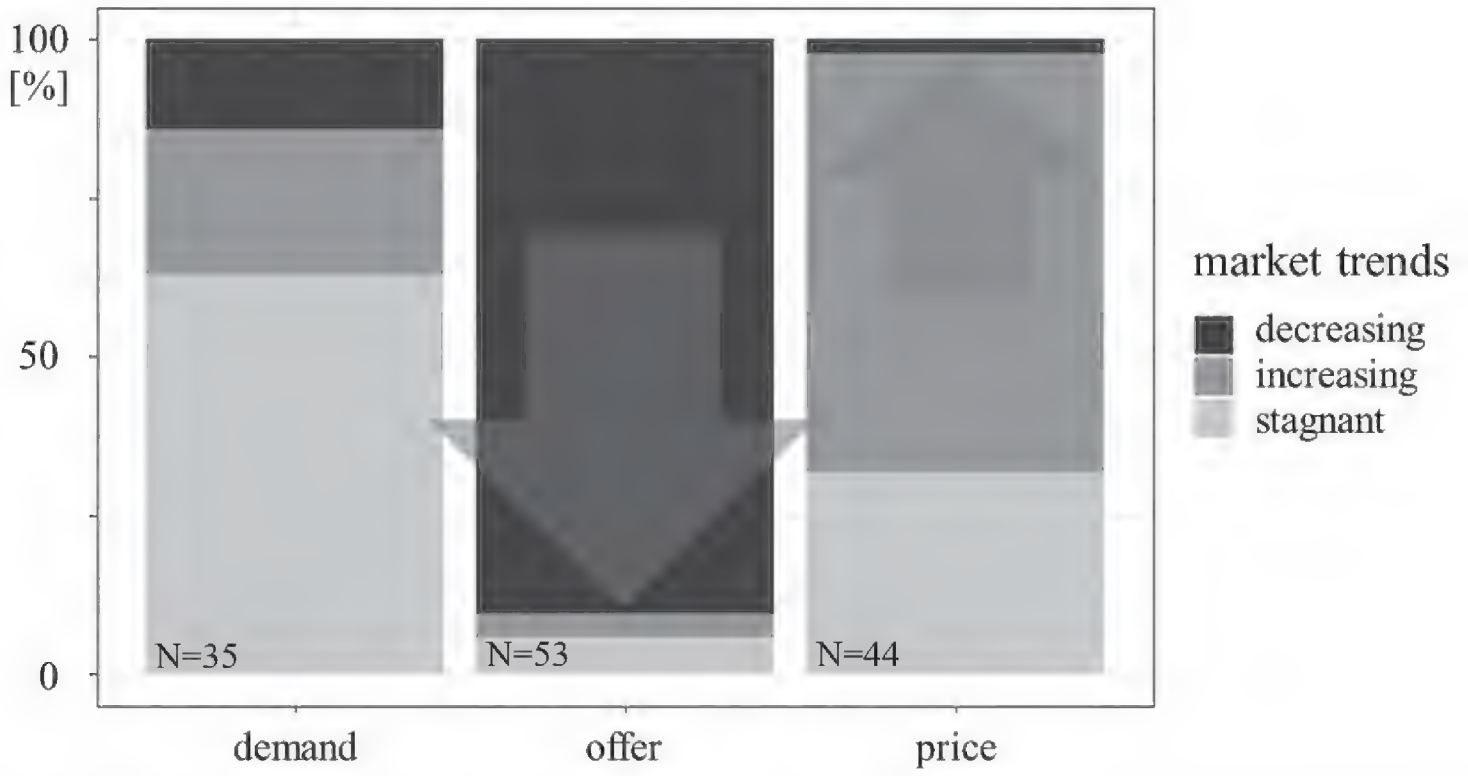

Figure 6. Households observing market changes regarding demand trends (N = 35), offer (N = 53) and prices (N = 44) for offered wildlife. There are differences between offer and demand (Fisher's exact test, $P = 4.08 \cdot 10^{-13}$), as well as offer and prices (Fisher's exact test, $P = 1.57 \cdot 10^{-20}$). Data was drawn from the respective interviews.

et al. 2016) to establish their social status among their peers. The high appreciation of wild meats, that many Lao people share was already documented in a prior study from Vientiane Province over 15 years ago: the majority of interviewed people stated that they would rather pay a higher price for a smaller amount of wild meat, than to pay a lower price for a larger amount of domesticated meat (Hansel 2004). Despite the risk of infectious diseases emerging from wildlife consumption (Zhang and Yin 2014, Kurpiers et al. 2016, Pruvot et al. 2019), our study reveals growing values of wild meats even today and similar statements were made in the urban environment and transition areas, whereas rural households were rather involved in trapping than paying high market prices. Minor but repeated information gathered about people's meat choice during our interviews indicates a preference for wild meats because of superstitious belief, its suspected health benefit and invigorating effect, as well as a status symbol that goes along with wild meat consumption. Other studies confirm this (Shairp et al. 2016, Sandalj et al. 2016).

Lao PDR

Wild meat remains a primary protein source in rural areas such as in Khammouane Province (Bennett 2002) and essential for people living in arboreous environments (Redford 1992, Milner-Gulland et al. 2002). The results of this study reflect this reality by showing a high level of participation by local people in hunting and trading activities in the rural areas of Khammouane Province. With the majority of Lao PDR´s citizens living in rural areas (Silverstein et al. 2018), their impact on local wildlife

Figure 7. Rats (*Leopoldamys sabanus*, *Niviventer* sp. or *Rattus* sp.) (upper left), squirrel (*Menetes berdmorei*) (upper right), and frogs (bottom) were most common traded wildlife. Phot. T. Ziegler.

populations is severe. The situation in Lao PDR resembles those in other regions in the world, such as Central Africa (Van Vliet et al. 2017), Indonesia (Harris et al. 2017) and Brazil (Chaves et al. 2019), with similar environmental, economic, and social settings.

The issue of unsustainable wildlife consumption in poor countries like the Lao PDR (Government's Office 2014) might even worsen in the future, as the global human population growth (Estrada 2016) and its demand for wildlife is estimated to increase the most in the world's least developed countries (FAO 2009). Furthermore, as Lao PDR is located in a biodiversity hotspot, the ultimate impact of the unsustainable hunting and trading of wildlife on global biodiversity and endemicity is unforeseeable.

Conclusions and recommendations

The current biodiversity crisis and the issue of its driving forces, such as the unsustainable usage of wildlife (GIZ and ProCEEd 2014), are complex problems which require multifaceted efforts to be implemented. A simple ban of trading wildlife is unlikely to succeed as it might shift the sales of wildlife and derived products from open market displays to the underground (Nooren and Claridge 2001). Without enforcing such

regulations, the law-obidiance is not ensured, as open sales of wildlife were observed during this study in close proximity to government signs stating the genereal ban of trading wildlife. If the trade shifted into the underground, it would dimmish the opportunity to monitor the trade and its trends. On the other hand, continuous trading observations would be aggravated. To get to the root of the issue, each driver for wildlife consumption needs to be addressed individually. Khammouane Province represented a hotspot of biodiversity as well as wildlife trade, and therefore requires appropriate attention by the local authorities. We recommend local authorities to assess the markets within the province capital Thakhek in particular, as they showed the highest quantity of wild meats. The markets at Namdik and Ban Kok turned out to be very active trade hubs for wildlife as well, regardless of the vertebrate group. This is presumably due to their advantageous location at Routes 12 and 13, which are the province's main connections across the international border between Lao PDR and Vietnam. Mahaxay May and Boualapha were found entirely inactive in terms of wildlife trade, although one household survey participant mentioned Boualapha as a place with occasional sales. Their market activities were probably replaced by the nearby market at Ban Kok. Thepsomebath and Ban Langkhang markets largely consisted of sellers from rural areas who are unable to afford stalls inside the market building. Rainy seasons seem to have a detrimental influence on sales activities, resulting in seasonal variation of documented activities. Additionally, Ban Langkhang is situated near the HNN NP where wildlife can be easily extracted. We gained information that before wildlife is offered here, it is mostly transported to Thakhek, where the demand is much higher.

Frogs, squirrels and rats were documented in almost every recorded instance, outnumbering other taxonomic groups by far (Fig. 7). Even though they are not in need of urgent protection now, further assessment of their natural populations in the NP should be conducted to better understand the hunting impact. Frequent trade of protected turtle and monitor lizard species on the other hand requires immediate interventions. Moreover, it is alarming that the trade and demand for keystone species like bears, civets and cat species could be easily witnessed.

The loss of certain species may cause a cascade of unforeseeable effects in the ecosystems. For example the loss of a species that others depend on can lead to subsequent extinctions of dependent taxa (Koh et al. 2004). Therefore, the biodiversity of tropical Southeast Asian countries like Lao PDR must be protected. Another known major obstacle in the conservation efforts is the lack of data (Novacek and Cleland 2001). Further investigations of the current level of diversity and distribution and population status of endangered species are urgently required.

Sharing a border with neighbouring China, one of the major wildlife consumers, significantly increases the species decline in Lao PDR (Srikosamatara et al. 1992). Strict and effective border controls should be established to reduce the amount of cross-border trade. During this study, many interviewees confirmed China as a main importer of wildlife poached in Lao PDR. The country's wildlife and their products are often trafficked across Vietnamese borders into China (WWF Indochina Program). New goals to better prevent wildlife associated crimes, including strengthening inter-

national cooperation, are supposed to be implemented until the year 2020 (Ministry of Natural Resources and Environment 2015). Rising awareness among Lao villagers could also support the conservation of wildlife, as a study on the effects of knowledge about wildlife laws in tropical Madagascar indicated that people with higher education/awareness are more likely to know about the wildlife laws and specific protected species and less likely hunt them (Keane et al. 2011). Not to mention that, to prevent wildlife trade and consumption implies a substantially reduced risk of wildlife-associated emergence of zoonotic parasites and pathogens in humans (Kapel and Fredensborg 2015, Greatorex et al. 2016, Borsky et al. 2020). As an immediate example, the outbreak of the coronavirus 2019 (COVID-19), primarily considered to be a consequence of consuming wildlife, has caused devastated damages on individual lives, society and economy (Galea et al. 2020, Fernandes 2020). Lastly, eco-tourism presents a great opportunity to combine conservation efforts and an alternative source of income. Former hunters with excellent knowledge of the forest and wildlife habitats can serve as professional wildlife tour guides. A similar approach is successful in the northern Lao Nam Et-Phou Loei NP (Butler 2009), where eco-tourism is operated, benefiting local villagers financially and motivating them to protect the forest and it's inhabiting species.

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Appendix I

Standardized questionnaire for the household surveys, arranged by categories of interest.

		Consumption
1	**Is wildlife consumed or traded by themselves or in the household?**	94% yes; n=63
1.1	If no, in the past?	50% yes; n=4
1.2	If ever, which animals?	n=61
		Food Purposes
2	**How often is wild meat consumed?**	2% daily, 39% weekly, 48% monthly, 11% annually; n=54
3	**What kind of meat is preferred?**	40% wild meat, 44% domesticated meat; 16% uncertain; n=63
4	**Is wild meat more expensive or cheaper than domesticated meat?**	38% cheaper, 35% more expensive, 27% uncertain; n=63
5	**What are the reasons for choosing wild meat?** (multiple choice)	48% taste, 43% health, 9% beliefs, 18% status symbol, 21% food variety, 29% necessity; n=56
		Medicinal Purposes
6	**Is wildlife used for medicinal purposes?**	32% yes; n=56
7	**What kind of medicine is preferred?**	13% wildlife-based, 67% conventional, 20% uncertain; n=63
		Market Situation
8	**Has the wildlife trade changed over time?**	84% yes; n=63
8.1	Changes in prices?	22% none, 46% increase, 2% decrease, 30% uncertain; n=63
8.2	Changes in offer?	5% none, 3% increase, 76% decrease, 16% uncertain; n=63
8.3	Changes in demand?	35% none, 13% increase, 8% decrease, 44% uncertain; n=63
9	**Is open display on markets avoided (by direct connections between trappers and costumers)?**	32% yes, 2% no, 66% uncertain; n=63
		Trapping & Trading
10	**Is the household involved in wildlife trading?**	16% yes; n=57
10.1	Is trading important for their livelihood?	44% yes; n=9
11	**Is the household involved in wildlife trapping?**	65% yes; n=55
11.1	Is trapping important for their livelihood?	76% yes; n=33
		Conservation
12	**Is there awareness about conservation statuses?**	89% yes; n=63
12.1	Is the Lao Protection List known?	7% yes; n=59
12.2	If so, could protected and unprotected species be differentiated?	25% yes; n=4